

Design of a 20,000 Gallon
Water Pumping Station

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T H E S I S

DESIGN OF A 20 M. GALLON WATER PUMPING STATION.

Object and Intent of Thesis:- It was the object and intent in the preparation of this thesis, to obtain a general scientific knowledge of the present day practice in equipping and operating a water pumping station, and to embody such knowledge as was acquired by a systematic study of engineering journals and trade papers in the plans accompanying this thesis. No attempt has been made to master the various details of construction and application as would be valuable and necessary to the expert in this particular division of engineering, but rather to make a general study of the subject which would be of value to the civil engineer.

General:- A water supply station to be efficient in service must be able to meet the maximum demand made upon it without hesitancy during the time of demand. At no time should the station be in such a crippled condition as to render it unable to supply no water to its consumers. That this may be true a certain reserve capacity should be provided to take care of such break-downs or stoppages as are liable to occur during the lifetime of the plant. It seems to be the modern tendency to take a certain risk in constructing pumping plants, and instead of providing double the capacity necessary, only a proportional increase to the nominal capacity is made. In large stations it may not be necessary to provide extra



engines and boilers, but reliance is placed upon the fact that engines and boilers are able to be crowded to a twenty-five percent. overload. Thus, in a station comprising five 20 M. gallon pumping engines, each with the ability to develop twenty-five percent. overload for short intervals, one engine could be out of service, and the remaining four engines by virtue of their overload would supply the total 100 M. gallons.

Although sufficient funds can generally be obtained to prosecute the construction of public enterprises in the most modern and up-to-date methods, still, due respect should be given to the economical feature of the work. The fixed charges can be computed with a fair degree of accuracy, but the variable items, such as fuel, labor, supplies and repairs, can but approximately be figured. The fixed charges comprise such items as interest, depreciation, insurance and taxation. Fuel will prove to be the most expensive item of the variable charges, and the station should be designed with such a fact in mind.

Buildings:- It is not within the province of engineers to design the architectural features of the buildings inclosing the pumping machinery and boilers. That responsibility should be left to the architect. The general dimensions, such as length and width, clearances and head room, location of doors in the wall between the engine and boiler rooms, the location

of windows in front of the boilers and the sizes and location of skylights should be given by the engineer. The design of the steel roof system should be made in detail by the engineer. The engineer should design all tunnels, wet walls, engine, boiler and building foundations.

The buildings must be of ample size in order that proper clearances can be provided between batteries of boilers and between the rear of the boilers and the wall between the boiler and engine rooms. Provision should also be made for the removal of defective or broken parts of the machinery without tearing out a wall or foundation of the building.

As light promotes cleanliness and cleanliness promotes plant efficiency, windows should be so located as not to allow dark corners, where refuse is able to be covered up in the darkness.

There are two methods of arranging the engine and boiler rooms with respect to each other. In the one case they are placed in one long building with a division wall between them. The tendency in the last few years, however, is placing the boilers with their rear ends directly opposite the steam ends of the engines. In this method the steam travel is less than in the first, and the steam piping system is more flexible. When engines and boilers are located back to back with respect to each other, one system of roof trusses

can be made to protect the entire floor space of the two rooms, or separate roof systems can be provided for the engine and the boiler rooms.

The aesthetic features of the building should be such as to make it an ornament to the community.

Boilers:- Two distinct types of boilers are in general use today for the generation of steam for power plant purposes - the water-tube and tubular boilers; and of the tubular boilers there is the internally fired and the externally fired type. Of the tubular type of boilers the internally fired is in more common use. These boilers are generally provided with a corrugated suspension furnace, the rear end of which is rivetted into the combustion chamber; the gasses pass through this furnace into the combustion chamber and from there they return through the tubes to the top of the front end of the boilers and are there passed through the uptake into the breeching. These boilers are in common use today, although since the perfection of the water-tube boiler it seems to be in the most general favor for power house work, especially where the load varies to any great degree.

In the water-tube boiler the gases of combustion do not pass through the tubes at any time. Instead they are thwarted in their travel by means of baffle walls and thus are made to strike at an angle on the outside of the tubes. After passing

three baffles (in general) the gasses pass into the breeching and then into the stack. In the water-tube type of boilers the water circulates through the tubes into an upper drum, which is kept half full of water (the other half comprising the steam reservoir), down a rear header or set of tubes. In this way a complete circulation of the water is kept going on, while the steam is being generated. This circulation causes the salts precipitated in the water to settle in a mud drum which is provided at the bottom of the rear header where they can be blown off into the sewer.

In the important question of circulation the water-tube boiler shows to advantage over the tubular boiler which has but little or no circulation unless a special furnace is used.

The water-tube boiler has also the advantage of quicker steaming and can be crowded to an overload of one-hundred percent. The last and perhaps the most important advantage shown by the water-tube boiler over the tubular is the one of safety. In the water-tube boiler there are no great volumes of water with enormous contained energy in the form of heat as in the case of tubular boilers. An ordinary sized tubular boiler has sufficient stored energy to blow it over a mile high in the air if all the energy exerted itself at once. This is not the case with water-tube boilers. A tube can rupture with only the result that a temporary shut-down is

necessary. No loss of life would result unless they were very near the boiler in which the rupture took place.

Of late, water-tube boilers are supported on an iron frame-work entirely separated from the brick setting. It has been found by experience that the rupture of a tube is liable to blow out a side wall, letting the boiler collapse, and in this manner causing great damage. When supported on a separate iron frame-work the boiler would not collapse.

In building the brick setting, care should be taken that no part of the mud drum is enclosed in the brickwork in such a manner as to prevent inspection. The mud drum is in such a position as to receive but little application of heat, and should, by the union of the moisture and sulphur contained in the fuel, sulphuric acid be formed and act upon the metal, a rupture is likely to take place.

Boilers as a rule are set in batteries of two, thus requiring less room and brickwork in the setting. It also reduces the expenditure in feed water and steam-piping, and affords a better location for a live steam purifier should it be used.

The furnace is perhaps the most important part of the boiler. The design of boilers has almost advanced to a standard. The furnace, however, presents a problem which must be worked out for each particular case. The specific kind of fuel which is to be burned must be analyzed and studied and the furnace

designed to burn that kind which will be most generally used. The principal source of loss is in the incomplete combustion of the volatile gasses. Furnaces of the Dutch-oven type are coming into quite extensive use. This allows the complete combustion of the volatile matter before it comes in contact with the comparatively cool surfaces of the boiler.

Mechanical stokers are coming in general use in large plants. They are cheaper than the labor, and they prove more efficient. For small plants a good fireman, however, can fire as economically and efficiently as a mechanical stoker.

One man can shovel sufficient coal to supply 500 H.P. of boiler, or six to eight tons in twelve hours. Where automatic stokers are used one man could handle 2000 H.P. of boilers.

Higher pressures are being used now than a few years ago, and from 150# to 200# gauge pressures are being used quite extensively. Higher pressure steam lends itself better to expansive working. In addition to higher pressures, the present-day tendency is to use superheated steam. The primary object in the use of superheated steam is to deliver dry steam to the engines. With the use of dry superheated steam there can be expected little or no cylinder condensation up to the point of cut off. Superheat on the other hand requires more fuel than does the same volume of saturated steam, and it is doubtful if greater than 125° superheat will prove economical. However,

up to 125° superheat a saving of from 1% to 2% in steam consumption can be expected for every 10° of superheat, according as the steam is wet or dry.

Upon the question of high pressures is dependent in many cases the selection of the type of boilers. As pressures reach 175 lbs. or 200 lbs. per square inch, gauge pressure, the use of tubular boilers requires the use of rather heavy metal in the boiler shell. Some authorities limit the thickness of the metal in the shell to $\frac{5}{8}$ inch. This is especially true in externally fired boilers of the tubular type. Unless a special furnace is used the heat is such on the outside of the shell as to render the metal liable to be burned. Steel is a good conductor of heat, but should the inside of the shell be coated with scale there is great liability of retarding the transference of the heat to the water that the shell will burn directly over the fire. This objection can be eliminated by building an arched furnace under the entire length of the boiler and so prevent the heat from coming in direct contact with the surface of the shell until the gasses are returned from the rear of the boiler through the tubes. With this device, tubular boilers can be used in many cases to an advantage.

In water-tube boilers the drums are the only parts of the boiler that have much thickness of metal, and in them the thick-

ness is comparatively small. Due to the rapid circulation of the water, also, very little scale is formed on the drum or tubes. In this respect the water-tube boiler offers little danger in the use of high pressures.

In the matter of head room and floor space the two types of boilers require about the same when fired by hand. When fired by chain grates, however, the tubular boiler requires more room in front of the boiler, thus increasing the width of the boiler room.

Notwithstanding the fact that water-tube boilers seem to have the greatest number of points of vantage to their credit, some recent pumping stations of large capacity have been equipped with tubular boilers, viz; the Springfield Avenue and Central Park Avenue Pumping Stations, of the City of Chicago, and also the New Lardner's Point Pumping Station, of the City of Philadelphia.

Steam Piping System:

No detail of a steam plant should demand more careful consideration and design than the system of steam piping. Upon the steam piping system, to a great extent, depends the plant efficiency, and large systems should be designed by those who make their design a specialty.

For high pressures, i.e.; pressures of 125# or over, extra heavy wrought iron pipes are used, with metallic packing and

gaskets, and for all sizes above 3" diameter flanged joints should be used. Bends of large radius should be used in connecting boilers to main steam header and in making the connection between the steam header and the engine. No pockets should be allowed in which the water of condensation could collect. Bends are used to provide proper expansion facilities, and such bends allow for expansion in all directions without undue torsion on the flanges. Patented expansion joints have been used to some extent, but greater reliance can be placed upon long radius bends. The pitch of all steam pipes should be in the direction of steam travel because there is less liability of a slug of water being formed and picked up. Should a small slug of water strike a valve or fitting with a velocity of steam, a crack would most likely result.

Steam pipes are generally so proportioned that the velocity of steam will not be greater than six thousand feet per minute. Recently, as high a velocity as eight thousand feet per minute has been used for saturated steam and from 8,500 to 10,000 feet per minute for superheated steam, varying in superheat from 0 to 250⁰ F. Being of a higher temperature than saturated steam, superheated steam is allowed a greater velocity than saturated steam in order that the loss in heat by radiation between superheater and engine is a minimum. The object,

primarily, of superheated steam is to deliver dry steam to the engine up to the point of cut-off, and this causes less cylinder condensation. The flow of steam causes a drop in pressure, but this drop in pressure does not necessarily mean a loss in energy, for the excess in temperature at the lower pressure is utilized in the superheating of the steam. This superheat causes less condensation and drier steam.

Duplicate systems of steam piping are no longer in general use, but the best pipe and best design, with properly distributed valves, is the most modern practice.

A complete system of drip and drainage piping should also be installed. There should be a drip and bleeder main, the former being trapped to the boilers, while the latter should be lead to the blow-off line. Into the drip header risers should be tapped, which are connected at the proper points to steam mains and engine pipes. The check valve in the drips should be so placed that no head is necessary to open it. A correct system of drainage will lessen condensation and eliminate all danger of carrying water of condensation over into the engines.

Bleeders are used to drain such pipes as have been out of use for a time and in which has collected water of condensation.

A separator should be placed in the steam line just ahead of the throttle valve to intercept any entrained moisture which would otherwise enter the engine cylinder. The water so inter-

cepted should be trapped back into the boilers by means of a high pressure steam trap.

Steam pipes should be well and entirely covered by means of some heat insulating material. Asbestos felt, mineral wool and magnesia are some of the more common heat insulators.

Valves should be so placed as not to form water pockets. Globe valves cause water pockets unless placed with their stem horizontal. Globe valves cause a drop in pressure. Gate valves can be set in any position. All valves of greater size than 5 or 6 inches should be provided with by-pass, to enable them to be opened when under pressure on one side only.

By proper arrangement of valves any boiler can be cut out of service without crippling the plant only to the extent of the one boiler.

Water Pipes:

In the line between the feed pumps and the boilers the water piping should be of the high pressure quality. On this side of the pump should be placed a hot water meter with a by-pass connection and a water relief valve ahead of it. This water relief valve affords a protection to the meter should the feed into the boiler suddenly stop. A check valve should be placed between the meter and the pump, as well as a globe valve to regulate the boiler feed.

The suction pipes should originate in the hot-well, heater or connect to a city main or water tank.

Feed pumps and water piping should be installed in duplicate in order to provide against a complete breakdown of one entire system.

There is now being installed in some plants a system of automatic boiler feed traps instead of boiler feed pumps. It is claimed that these traps will feed water into the boiler and consume only one percent. of the steam generated, whereas boiler feed pumps require from three to fifteen percent. On the other hand, boiler feed pumps are known to be reliable and are easily regulated.

Feed Water Heaters: Feed water heaters are of two types - the open and the closed heater.

In the closed heater, the boiler feed water is driven from the feed pump through coils of pipe enclosed in a metallic casing. Into this casing the exhaust from the engines and auxiliaries is received, and as the exhaust steam comes in contact with the pipe coils through which the boiler feed water flows, the water is heated.

In the open heater, the heater merely takes the place of a hot-well, the discharge from the air pumps being received in the reservoir of the heater. This water is intercepted by pans at different elevations and in this manner a large surface of shallow water is obtained in the heater.

The exhaust steam enters the heater and comes in direct contact with the water. An oil separator must be provided to remove the cylinder oil from the exhaust steam before it enters the heater, otherwise this oil would be pumped into the boilers, which is dangerous. The heater is vented to the free air to allow all excess vapor to escape. An overflow and a blow-off pipe must also be provided.

Heaters effect a net saving in the fuel cost of about one percent. for every 10 or 11 degrees rise in temperature they afford the feed water.

Economizers: Economizers are coils of pipe placed in the flues of stations to utilize, as far as possible, the heat in the escaping gases which would otherwise be wasted. The feed water is driven through these coils before reaching the boiler and in this way it takes up a certain amount of the heat contained in the flue gases. Where every expedient conducive to economy is necessary, the economizers would undoubtedly provide a saving in the fuel cost, and about to the same extent as a feed water heater. However, economizers are an expensive installation and an engine is necessary to drive the mechanisms which clean the pipes of the ever adhering soot, etc. Economizers also require a greater provision in draft, thus increasing the cost of the stack.

Live Steam Purifiers: Where the water available for boiler feed purposes contains salts that will precipitate when heated and under pressure, live steam purifiers have proven very efficient in purifying such feed waters.

In live steam purifiers, the pressure in the purifier is the same as in the boiler, made so by connecting the purifier to the boiler by a steam pipe. A large surface for shallow water is provided, and the boiler feed water is forced into the purifier, where it is heated by contact with live steam to the temperature of the steam, and at the same time it is subject to boiler pressure, and by these two agencies the salts are precipitated and they adhere to the surfaces over which the water flows. These surfaces, when they become sufficiently coated with the precipitated salts, are removed and cleaned.

The water flows from the purifier to the boiler by gravity, as the purifiers are necessarily located higher than the water line in the boilers.

Miscellaneous: Boilers must be provided with safety valves, gauges for pressure and height of water in boiler. They must be provided with man-holes and hand-holes. A blow-off connection to the sewer is necessary to drain off all sediment and scale which collects in the mud drum or bottom of the boiler.

Stack: The fundamental office of the smoke stack is

to provide a sufficient draft to enable the fuel to be converted into heat at such a rate as will be necessary to supply the heat required for the generation of steam at its maximum rate of consumption. The chimney should be of ample height and area to accommodate the maximum flow of gases; and the draft for all loads up to a maximum should be controlled by a regulating damper in the uptake of the boiler.

Draft is due to the difference in pressure of the heated gases on the inside of the stack and the colder air on the outside. In the passage of the gases up the chimney, the colder air is forced through the grates and there becomes heated, thus making the circulation continuous. The intensity of the draft is usually measured in inches of water.

The pressure of the draft is distributed along the circuit from the ash door to the top of the chimney. The draft losses are due to the friction of the gases in the stack, in the breeching, the boiler damper, baffles and coal on the grate surface. A large percentage of the draft is sometimes required to force the cold air through the bed of coals.

When natural draft is insufficient without the use of absurdly high chimneys, forced draft is provided for by means of a fan and engine.

Engines: Pumping engines only will be considered. Remarkable advances in the design of pumping machinery have been made in recent years.

In 1890 a duty of 150,000,000 foot pounds per thousand pounds of dry steam was considered an economical development in the case of high duty pumping engines. In 1904 a vertical triple expansion pumping engine, built by the Allis-Chalmers Co., for the City of St. Louis, Mo., developed nearly 177,000,000 foot lbs. per 1000 lbs. dry steam. This engine is of 20,000,000 gallons capacity per twenty four hours. The piston speed is two hundred feet per minute, and the head pumped against is two hundred feet.

The present tendency is to increase the rotative and piston speeds, and to provide a larger and more direct passage from the suction to the delivery mains. Piston speeds have generally been limited until within the last four or five years to about two hundred feet per minute, but lately there is a tendency to increase this speed to about twice its former value, or four hundred feet per minute. This increase of rotative and piston speeds has chiefly been brought about by the demands of the purchasers, and this demand has become so general that many makers of high duty pumping engines advocate the use of higher piston speeds. In building engines of the higher

speed kinds, there is a resulting smaller first cost. In consequence of the higher speeds, there is required smaller areas, which materially effects a lessening in the cost of installation.

Heretofore, when high speed pumping engines were called for, it has been considered necessary to use mechanically operated water valves. It is now believed by a great many experts in pumping engine practice that fully as good results can be obtained from ordinary voluntary pump valves.

The rotative speed, where formerly specified as twenty-five or thirty revolutions per minute, has now increased to fifty or sixty revolutions per minute, and the pumps must be so designed, even with these higher speeds, to allow an increase in the rotative speed of twenty-five percent. for short runs.

As a result of higher speeds, however, there is to be expected an ensuing greater cost in maintenance on account of the greater wear and tear. These higher speed engines, too, are not expected to last as long as the slow speed engines.

In regard to the types of engines, they can be divided into two general types: the horizontal and the vertical; and these may be either simple, compound or multiple (generally triple) expansion, and condensing or non-

condensing. These may be further divided into two kinds: the crank-and-fly-wheel or the high-duty attachment of balancing water plungers.

The vertical engine requires greater head room, whereas, on the other hand, the horizontal engine requires greater floor space, and these two practically balance one another so far as the cost of the building is concerned. The land, foundations, boilers and stack will generally prove smaller in cost for the vertical than for the horizontal engine, while the reverse is true as regards first cost of sub-foundations and buildings. The vertical engine in itself is the more costly as regards first cost. The cost of steam piping and auxiliaries is approximately the same for either engine. The maintenance of the engines is approximately the same.

A comparison of the duty developed by the two types may be made by referring to the following table:

Type	Stage	Duty	
		per 1000# dry steam	per 1000# steam superheated 500° F.
Vertical	Triple	170,000,000	185,000,000
Horizontal	"	160,000,000	175,000,000
"	Compound	150,000,000	162,000,000

The vertical, triple expansion engine for capacities of 10 M. gallons per twenty-four hours and over is the most economical and satisfactory when observed from any point of view. By engine builders it is claimed to be an ideal machine, having, as it does, three plungers which give a very steady flow and make it eminently adaptable for direct service pumping.

Multiple expansion is used primarily to lessen the range of temperature in any one cylinder, and thus reducing the cylinder condensation. Tests upon many triple expansion pumping engines seem to show the highest duty when working at a steam pressure of from 125 lbs. to 150 lbs. per square inch by guage.

Superheated steam, as has been before remarked, will afford an increase in economy only when superheated about 100 or 125 degrees F. When the superheat is larger than 100 or 125 degrees it becomes necessary to make special provisions for this higher temperature in the engine cylinders which results in a greatly increased cost.

All engine cylinders are surrounded by steam jackets, the office of which is to maintain, as far as possible, a uniform temperature on the cylinders. These steam jackets consist merely of a narrow space surrounding the steam cylinder and enclosed by an outer casing of metal. The steam is supplied to these jackets by running a pipe from the main engine line

to the jackets. The pressure of the jacket steam is then the pressure at the throttle. The condensed steam in the cylinder jackets is trapped by means of a high pressure steam trap into the hot well or feed water heater.

A separator should always be placed just outside the throttle valve on the engine line. This affords a means of intercepting any entrained water that would otherwise be carried into the engine cylinder. This intercepted water should be trapped into the hot well or heater.

In many cases a reheater is placed on the exhaust pipe between the high and intermediate, and the intermediate and low pressure cylinders to preserve the British Thermal Units in the exhausting steam as far as possible. These reheaters consist of a steam-tight cylindrical vessel through which the exhausting steam passes. Inside these reheaters are passed coils of copper pipe; through these coils is passed steam obtained from the same source as the jacket steam supply, and the condensation from which is trapped to the hot well.

Condensers are of two kinds, the surface and the jet. The jet condenser consists of a pump supplying a jet of cold water, which by an arrangement of the exhaust pipe from the low pressure cylinder is brought in contact with the exhaust steam. The steam is thereupon condensed, and by this condensation of the steam on the atmospheric side of the steam piston

the back pressure of the atmosphere is reduced to about three pounds absolute.

In the surface condenser the same effect is produced but by a different design. The surface condenser consists of a cylindrical drum into which the exhaust steam enters. Inside this drum are a number of tubes through which is flowing cold water driven by a circulating pump. When the steam comes in contact with the colder surfaces of these tubes condensation immediately takes place, thus relieving the back pressure on the engine. An air pump is also supplied which pumps the condensed steam from the condenser and also creates a partial vacuum in the condenser. This water of condensation is delivered to the hot well or heater and is used again and again for boiler feed purposes. The air and circulating pumps may be driven separately or driven by direct connection to the main engine. It is generally considered advisable to operate these pumps separately as they can then be better regulated. The air pump should also be connected to the suction pipe of the main engine, so that in case of a shut down the water can be raised into the suction pipe by first starting the small pumps and then the engines can be started pumping water immediately. An oil separator should be placed on the exhaust pipe between the low pressure cylinder and the condenser to divert any cylinder oil the exhaust steam may contain.

There should be air chambers of large capacity on each discharge pipe, and an equalizing pipe should connect these air chambers. These chambers produce a uniform flow of water into the distributing pipes. The chambers should be connected to an air compressor, that they may be charged at necessary intervals.

In case the suction pipes are under head, an air chamber should also be placed on them. These air chambers act as a cushion and prevent a water hammer, due to the stoppage of the water at the end of each stroke.

The steam valves are Corliss in the high pressure, usually Corliss in the intermediate pressure and poppet in the low pressure cylinder.

Description of the 20 M. Gallon Water Pumping Station.

Two drawings are attached to this thesis and made a part hereof. The one drawing shows the general arrangement of the boilers, boiler room and accessories, while the other shows the general arrangement of the engines, engine room and accessories.

Boiler Room.

Boilers: Through the courtesy of the Chicago Office of the Babcock and Wilcox Boiler Co., a drawing of a 170 H.P. water tube boiler was obtained, and this, though modified

in some details, is essentially reproduced in the drawing of the boiler room.

The boiler represented has a grate area of 40 sq. ft., and a heating surface of 1703 sq. ft. Ten sq. ft. of heating surface are allowed per boiler horse-power, while one sq. ft. of grate area will develop four boiler horse-power with the proper fuel and under favorable conditions of draft and firing. The boiler contains eighty-one tubes, eighteen feet long. The headers are inclined in all boilers when designed for pressure of 150 lbs. or greater. The drum is 42" in diameter, the upper half of which comprises the steam reservoir. For boilers of greater capacity than 200 H.P. two drums are provided.

Three boilers are provided, two act in one battery and one set separately. An allowance in space is made which is sufficient to accommodate another boiler of the same size should this fourth boiler be necessary. Two boilers of 170 H.P. each are ample in capacity to supply steam for the engines, but it is advisable to install an extra unit to provide for any damages that may occur to one or both boilers which are in service. The boilers are slightly in excess of the needed capacity, but an excess in boiler capacity is advisable to allow insurance restrictions which are likely to be placed upon them after some years of service.

Boiler Feed Pumps: Two boiler feed pumps are supplied, each 6"x4"x6", and either capable of delivering into the

boilers water necessary to run the entire station. It is necessary to provide two systems of boiler feed in order that no stoppage occurs should one system of boiler feed be out of service. Either pump is of the piston pattern, duplex and double-acting, and designed to pump against a water pressure of 150 lbs. per sq. in. The pumps are located centrally with respect to the boiler arrangement for the purpose of balancing as far as possible the water piping.

Heater: A 500 H.P. open heater is shown on the drawing in close proximity to the boiler feed pumps. This heater receives the discharge from the air pumps and is also connected to the city mains. Exhaust steam is passed through the heater from the air pumps, the air compressor, the electric light engine, and there is also provided pipes to receive the exhaust from the main engines should these be run non-condensing. It is vented to the free air.

Steam Piping: Steam is taken from each boiler by a 6" horizontal 90° bend. This bend connects into an 8" main steam header which runs lengthwise with the boiler room over the boilers. From this header the steam is delivered to the engines by 6" engine pipes. Horizontal bends connecting the boiler and steam header allow a lower location of the roof truss. Two valves are provided between each boiler and the steam header. This is a necessary precaution in that it affords

a better protection to a boiler repairman should it be necessary for him to enter the drum of a cold boiler when the header was under steam. Stop valves are provided at the engine pipe connections. All steam for driving the auxiliaries of the plant is taken from the main steam header.

Water Piping: The suction piping is so arranged that water may be drawn by either boiler feed pump from the heater or directly from the city main. On the suction line only gate valves are used.

The discharge from each boiler feed is into a header (not shown on drawing). A 3" hot water meter is so inserted into the feed line between the pumps as to make it impossible for water to be fed into the boilers without being registered. In this way an easy check upon the performance of the boilers is rendered available.

From the boiler feed header the water is delivered into the boiler through brass bends. On the pipes leading to the boiler is placed a check valve and a globe valve. The flow is regulated by means of the globe valve and the check valve provides against a backward flow of water.

A water relief valve is placed between the pumps and the meter as a matter of protection for the meter.

The mud drum of each boiler is connected to a blow-off pipe running lengthwise with the boiler room and located in

the pipe trench behind the boilers. This blow-off pipe terminates in a blow-off basin outside the boiler room. The blow-off basin is vented to free air. It is also drained to the sewer.

Engine Room.

A general plan and a side elevation of the engine is shown on the drawing. The floor of the engine room is considered as removed in the plan.

Engines: Three engines are shown - one is the reserve, and takes the place of one of the regular engines should either be placed out of duty. Each engine is of 10 M. gallons daily capacity.

Through the courtesy of Mr. Henry A. Allen, Consulting Engineer, Chicago, a blue-print of a 10 M. gallon, horizontal, triple-expansion, crank and fly-wheel pumping engine was obtained, and it is reproduced in general on the drawing, and marked Engine No. 1.

The piston rods extend in either direction from the pistons and connect on the one side to the water plungers, and on the other ^{side} ~~wise~~ to the connecting rod which in turn connects to the crank shaft. Steam is delivered to the high pressure cylinder by a 6" pipe, and from the cut-off to the condenser it passes through the ordinary expansions of a triple expansion engine.

The engine has two fly-wheels ten feet in diameter. The diameter of the high-pressure cylinder is 14", of the intermediate pressure 26", and of the low pressure cylinder 50". The plunger diameter is 10" and the stroke of the engine is 42".

Suction and Discharge Piping: Water is delivered into a wet well where the suction pipes of the engines originate. The sizes of the suction pipes are 20 inches. A foot valve and strainer are provided on the end of the suction pipe. The delivery pipe from each engine is 16" in diameter. A check valve is provided on the discharge pipes. The delivery pipes should, as soon as leaving the engine, be directed downward and enter the ground in the basement of the engine room. A gate valve is provided on the delivery pipe of each engine.

Condensers and Air Pumps, etc: On the suction line is arranged a condenser. This condenser has 800 sq. ft. of cooling surface which is composed of $\frac{3}{4}$ " brass ^{pipes.} rods. As the steam is condensed the water of condensation is delivered through an air pump to the heater to be used over as boiler feed water. An oil separator is placed on the exhaust pipe between the low pressure cylinder and the condenser to separate the cylinder oil from the exhaust steam.

The air pumps are vertical, single acting and have a bucket diameter of 18" and steam cylinders of 7" diameter. The stroke

is 10". Only two air pumps are provided, but the piping is so arranged that either pump can relieve either condenser.

The air compressor is of such size as to supply 40 cu. ft. of free air per minute. The air is delivered to the air chambers by $\frac{3}{4}$ inch pipe and the air chambers on either pump of each engine are connected together.

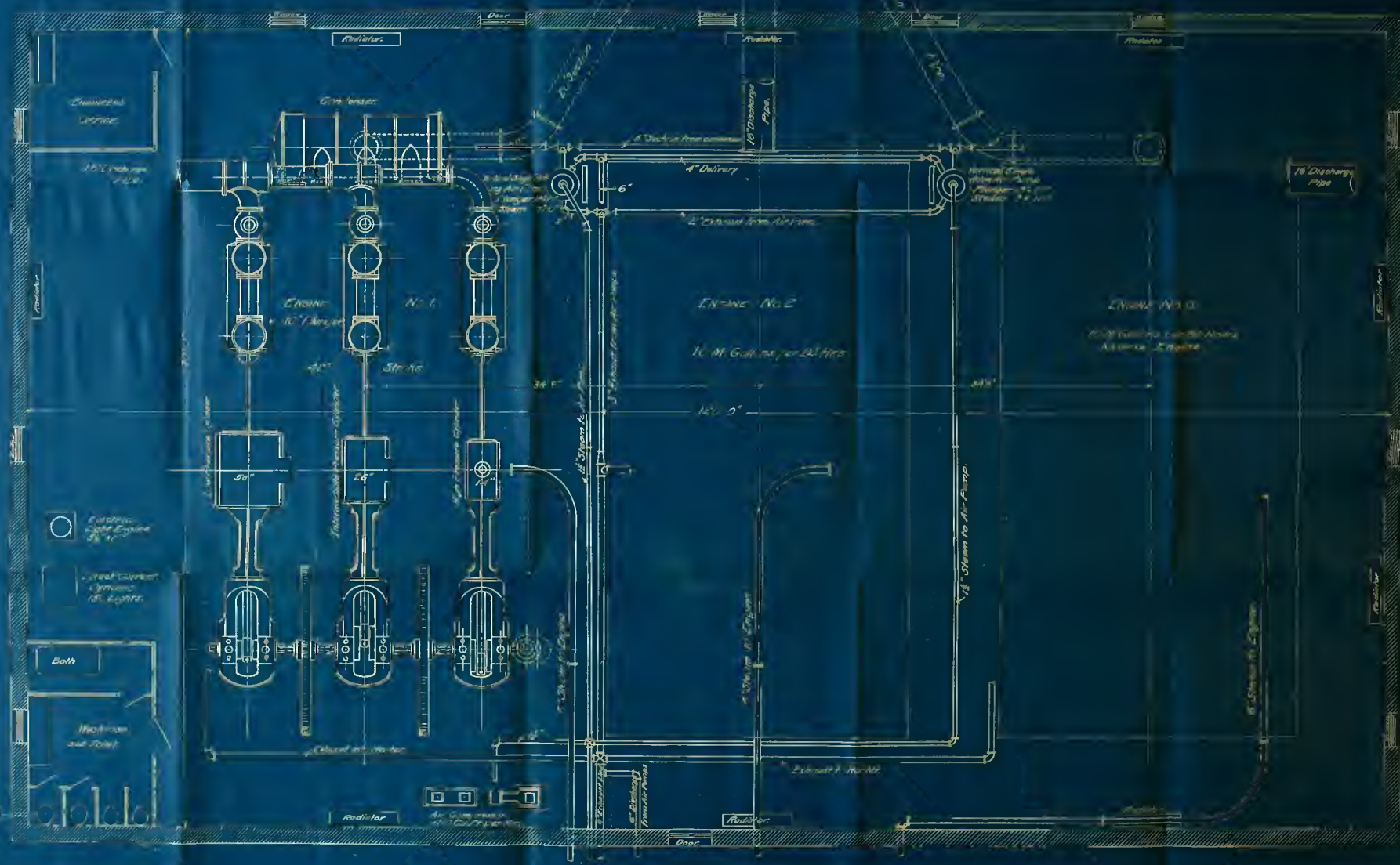
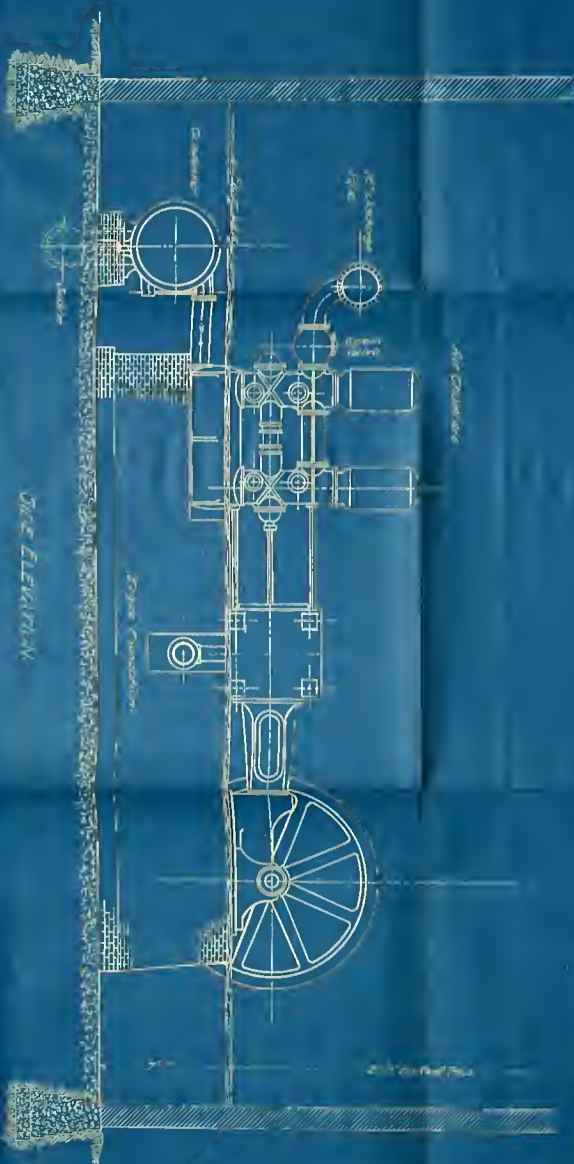
Provision for lighting the plant is made by furnishing direct current dynamo and an engine to drive it. The dynamo is of 150 light capacity and the engine is a $5\frac{1}{2} \times 10$.

The heating of the station is by means of exhaust steam. The radiators are connected up to the exhaust main and when heat is desired a certain amount of exhaust steam is used for this purpose.

Ample space is allowed between the engines and between the engines and the walls. An engineers office is also located in one corner of the building and in the opposite corner is the toilet and bath room.

The accompanying drawings portray in a manner the object and intent of this thesis, and they are submitted herewith.





PLAN OF

ENGINE ROOM

GENERAL ARRANGEMENT
OF PUMP AND ENGINE ROOM FOR
20 M. GALLON FURNACE STATION
PRESENTED WITH THESIS
ATMOS. INSTITUTE OF TECHNOLOGY
JUNE 1975







